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Instrumented Assessment of Physical Activity Is Associated With Muscle Function but Not With Muscle Mass in a General Population

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Abstract

Objectives: Self-reported physical activity has shown to affect muscle-related parameters. As self-report is likely biased, this study aimed to assess

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the association between instrumented assessment of physical activity (I-PA) and muscle-related parameters in a general population. **Method:** Included were 156 young-to-middle-aged and 80 older community-dwelling adults. Seven days of trunk accelerometry (DynaPort MoveMonitor, McRoberts B.V.) quantified daily physical activity (i.e., active/inactive duration, number and mean duration of active/inactive periods, and number of steps per day). Muscle-related parameters included muscle mass, handgrip strength, and gait speed. **Results:** I-PA was associated with handgrip strength in young-to-middle-aged adults and with gait speed in older adults. I-PA was not associated with muscle mass in either age group. **Discussion:** The association between I-PA and muscle-related parameters was age dependent. The lack of an association between I-PA and muscle mass indicates the relevance of muscle function rather than muscle mass.

Keywords

motor activity, sarcopenia, muscle strength, aged, activity monitoring, physical performance

Introduction

Higher levels of physical activity and lower levels of sedentary behavior are important factors in human health and well-being (Penedo & Dahn, 2005). Particularly at higher age, physical activity is related to a lower risk of various major age-related diseases (Abioye, Odesanya, Abioye, & Ibrahim, 2015; Behrens et al., 2015; Behrens & Leitzmann, 2013; Castaneda et al., 2002; Manson et al., 2002), lower overall mortality (Hupin et al., 2015) and mobility disability in older adults (Leveille, Guralnik, Ferrucci, & Langlois, 1999; Pahor et al., 2014). Higher physical activity levels are associated with higher absolute muscle mass and higher handgrip strength in older males (Baumgartner, Waters, Gallagher, Morley, & Garry, 1999; Gomez-Cabello et al., 2014) and higher physical activity levels are associated with better physical performance in older females (Martin, Syddall, Dennison, Cooper, & Sayer, 2008). However, these studies measured physical activity using questionnaires while it has been shown that physical activity assessed by means of questionnaires is often over- as well as underestimated, as it is affected by recall and interpretation bias (Baranowski, 1988; Prince et al., 2008).

Muscle mass, muscle strength, and physical performance are important measures of the diagnostic process of sarcopenia (Cruz-Jentoft et al., 2010; Fielding et al., 2011; Studenski et al., 2014). The pathophysiology of sarcopenia is multifactorial, including physical inactivity (Rolland et al., 2008). In

older males, higher levels of self-reported physical activity via questionnaires were found to be associated with a reduced risk of sarcopenia (Ryu et al., 2013). A major flaw of questionnaire-based physical activity measurements is that they often overlook short bouts of lower intensity leisure activity. As this level of physical activity comprises most of the activities of older adults (Tudor-Locke & Myers, 2001; Westerterp, 2008), instrumented assessment of physical activity (I-PA) provides a better assessment of actual physical activities (Harris et al., 2009). I-PA has been shown to reliably quantify various physical activity measures in older adults (van Schooten et al., 2015).

The aim of this study was to assess the association between I-PA and muscle-related parameters in young-to-middle-aged adults and older adults from a general population.

Method

Study Design

This cross-sectional cohort included 253 community-dwelling participants (169 young-to-middle-aged adults and 84 older adults being 70 years and older) recruited from the Grey Power debate events which took place in November 2014 at the VU University Medical Center Amsterdam, The Netherlands. The Grey Power debates were freely accessible lectures for the general population to promote healthy aging and attracted a predominantly vital and motivated group of socially active community-dwelling participants. No exclusion criteria were applied. This research was reviewed and approved by the medical ethical committee of the VU University Medical Center Amsterdam, The Netherlands. All participants gave written informed consent.

Characteristics

Questionnaires were used to determine age; sex; subjective fulfillment of the recommended Dutch physical activity guideline defined as 30 minutes of moderate physical activity for at least 5 days (Kemper, Ooijendijk, & Stiggelbout, 2000; Riebe et al., 2015); use of a walking aid; pain during movement; history of falls; current smoking; number of medications used; and multimorbidity. The question "Do you participate in 30 minutes of moderate physical activity for at least 5 days a week?" was used to assess the subjective fulfillment of the recommended Dutch physical activity guideline. Multimorbidity was defined as the presence of two or more chronic diseases including hypertension, myocardial infarction, stroke, chronic obstructive pulmonary disease, cancer, diabetes mellitus, osteoarthritis, and Parkinson's

disease. Body mass was assessed to the nearest 0.1 kg, and height was assessed to the nearest 0.1 cm using a height and weight measuring system (DS-102; Dong Sahn Jenix Co., Seoul, Korea). Body mass index (BMI) was calculated by body mass (kg) divided by height squared (m) and expressed in kg/m². Body mass was derived from direct segmental multifrequency bio-electrical impedance analysis (DSM-BIA; In-Body 230; Biospace Co., Ltd, Seoul, Korea), and height was derived from the height and weight measuring system (DS-102; Dong Sahn Jenix Co.).

Instrumented Physical Activity

Physical activity was assessed by use of a triaxial accelerometer (DynaPort MoveMonitor, McRoberts B.V., The Hague, The Netherlands) during seven consecutive days. The accelerometer was placed dorsally on the trunk at the level of L5 and attached with an elastic belt. Acceleration data were collected with a sampling frequency of 100 Hz and a range from -6 to +6 g. Participants were instructed to wear the accelerometer at all times except during aquatic activities such as showering and swimming. Periods of nonwearing, lying, sitting, standing, and locomotion were identified using commercially available software (MoveMonitor; McRoberts B.V., The Hague, The Netherlands). The duration of activity was defined as the sum of the total duration of standing and locomotion and expressed in minutes per day. The duration of inactivity was defined as the sum of the total duration of lying and sitting and expressed in hours per day. The used algorithm has demonstrated validity for physical activity classifications in healthy adults (de Groot & Nieuwenhuizen, 2013) and in community-dwelling older adults (Dijkstra, Kamsma, & Zijlstra, 2010). I-PA included the following measures: active duration (minutes/day), inactive duration (hours/day), number of active and inactive periods per day, mean duration of active periods (seconds/period), mean duration of inactive periods (minutes/period), and number of steps per day. Unclassified movements ("shuffling") were excluded from the analyses as the detection of shuffling in daily life conditions is inaccurate (Dijkstra et al., 2010). I-PA measures were averaged over valid days only, defined as a wearing time of the MoveMonitor for at least 75% (18 hours) of the day (Hart, Swartz, Cashin, & Strath, 2011; Matthews, Ainsworth, Thompson, & Bassett, 2002). If at least four valid days per participant were available, the participant was included in the analysis (van Schooten et al., 2015). Instrumentally assessed fulfillment of the Dutch physical activity guideline was done by use of algorithms provided by McRoberts B.V., The Hague, The Netherlands, thereby taking into account that the duration of bouts in moderate physical activity should endure for at least 5 minutes (Kemper et al., 2000). Of the 253 participants, data of

17 (6.7%) participants were excluded due to missing data on I-PA ($n = 2$) or having less than four valid measurement days ($n = 15$), leaving 236 participants for the present analysis.

Muscle-Related Parameters

Muscle-related parameters included absolute and relative muscle mass, handgrip strength, and gait speed. Body composition was assessed using direct segmental multi-frequency bioelectrical impedance analysis (DSM-BIA; In-Body 230; Biospace Co., Ltd). DSM-BIA is considered a valid tool to estimate muscle mass in healthy adults varying in age (Janssen, Heymsfield, Baumgartner, & Ross, 2000). The used DSM-BIA in the present study is considered a valid tool when validated against dual-energy X-ray absorptiometry (DEXA; Hurst et al., 2016; Karelis, Chamberland, Aubertin-Leheudre, & Duval, 2013; Ling et al., 2011). Measures of absolute muscle mass were skeletal muscle mass (SM) in kilograms and skeletal muscle mass index (SMI; SM divided by height^2 ; Janssen, Baumgartner, Ross, Rosenberg, & Roubenoff, 2004). The used measure of relative muscle mass was SM percentage (SM as a percentage of body mass; Janssen, Heymsfield, & Ross, 2002). Data on muscle mass were missing in seven participants (3.0%) due to the presence of a pacemaker. Handgrip strength was measured using a handheld dynamometry (JAMAR hand dynamometer; Sammons Preston, Inc., Bolingbrook, IL, USA) 3 times for each hand (Reijnierse et al., 2017). The maximum score was used for analyses and expressed in kilograms. Gait speed was assessed using a timed 4-m walking test at normal pace from a standing start using a stopwatch. Walking distance was longer than the required 4 m to prevent participants from slowing down before reaching the 4-m line. The fastest time of two trials was used for analyses, and gait speed was expressed in meters per second (m/s).

Statistical Analysis

Normally distributed continuous variables were presented as mean and standard deviation (*SD*). Skewed (non-Gaussian) distributed continuous variables were presented as median and interquartile range (IQR).

Muscle-related parameters were standardized into gender-specific z scores, to allow for direct comparison of effect sizes of I-PA with muscle-related parameters. For comparative interpretation between I-PA, number of steps per day was divided by 1,000 and numbers of active or inactive periods were divided by 100. The association between I-PA and muscle-related parameters was analyzed using multivariate linear regression models. First, analyses were performed in the total population; subsequently, to correct for possible nonlinearities in the

associations, analyses were performed using a dichotomous stratification for age with a cutoff value of 70 years. The cutoff value for age was determined using the Jonckheere–Terpstra test. Analyses were adjusted for age and sex (Model 1) and additionally for specific muscle-related parameters as described elsewhere (Model 2; Reijnierse et al., 2015). Absolute muscle mass (SM in kg and SMI) was adjusted for absolute fat mass. Relative muscle mass (SM%) was adjusted for body mass. Handgrip strength was adjusted for body mass and height. Gait speed was adjusted for height. The following variables were checked for being confounders—pain during movement, multimorbidity, and number of medications used—but were not included in the adjustment models as they were not identified as confounders. The interpretations of the results of the multivariate linear regression analysis are as follows: One *SD* increase of I-PA is associated with the effect size times *SD* ($\beta \times SD$) higher/lower of the muscle-related parameter.

Statistical Package for the Social Sciences (SPSS, version 22 for Windows) was used to perform the statistical analyses, and *p* values below .05 were considered statistically significant. Visualization was performed using GraphPad Prism version 6.3.

Results

Table 1 shows the participant characteristics. Median wearing time of the accelerometer was 6.9 days (IQR = 6.8–7.0) in both age groups. Active duration, number of active and inactive periods, and number of steps per day were higher in the young-to-middle-aged adults compared with the older adults. Inactive duration and mean duration of inactive periods were lower in the young-to-middle-aged adults compared with the older adults. Mean duration of active periods was comparable between groups. All muscle-related parameters were higher in young-to-middle-aged adults compared with older adults. A total of 119 (76%) young-to-middle-aged adults and 72 (90%) older adults reported to meet the recommended Dutch physical activity guideline, while I-PA indicated that, respectively, 37 (24%) and 13 (16%) participants objectively met these criteria.

Associations Between I-PA and Standardized Muscle-Related Parameters

In young-to-middle-aged adults, active duration and number of active periods were positively associated with handgrip strength, but not with the other muscle-related parameters (in Model 2). Mean duration of active periods, inactive duration, and number of inactive periods and mean duration of inactive periods were not associated with muscle-related parameters. The number of steps

Table 1. Participant Characteristics.

	Young-to-middle-aged adults	Older adults
	<i>n</i> = 156	<i>n</i> = 80
Age, median (IQR)	63.1 (53.7-66.9)	74.4 (72.4-78.0)
Male, <i>n</i> (%)	51 (32.7)	32 (40.0)
Walking aid, <i>n</i> (%)	1 (0.6)	1 (1.3)
Pain during movement, <i>n</i> (%)	43 (27.6)	24 (30.0)
History of falls, ^a <i>n</i> (%)	20 (12.8)	17 (21.3)
Current smoking, <i>n</i> (%)	7 (4.5)	4 (5.0)
Multimorbidity, ^b <i>n</i> (%)	15 (9.6)	18 (22.5)
Number of medication used, median (IQR)	0 (0-2)	1 (0-3)
Anthropometry		
Height (cm)	171.5 (9.2)	168.3 (8.3)
Body mass (kg)	74.4 (12.2)	75.0 (13.1)
BMI (kg/m ²)	25.3 (3.8)	26.3 (3.8)
Fat mass (kg) ^c	21.5 (8.8)	24.6 (8.2)
Instrumented physical activity		
Wearing time (days), median (IQR)	6.9 (6.8-7.0)	6.9 (6.8-7.0)
Active duration (minutes/day)	279.3 (61.9)	256.7 (67.2)
Number of active periods (per day)	1,553 (429)	1,407 (426)
Mean duration of active periods (seconds/period)	11.1 (2.0)	11.3 (2.2)
Number of steps (per day)	9,265 (2,969)	7,327 (2,507)
Inactive duration (hours/day)	18.6 (1.1)	19.0 (1.2)
Number of inactive periods (per day), median (IQR)	148 (128-178)	132 (111-160)
Mean duration of inactive periods (minutes/period)	7.5 (2.5)	8.9 (2.8)
Muscle-related parameters		
SM (kg) ^c	29.3 (5.8)	27.6 (5.8)
SM (%) ^c	39.5 (5.2)	36.6 (4.9)
SMI (kg/m ²) ^c	9.9 (1.1)	9.6 (1.3)
Handgrip strength (kg)	37.0 (11.2)	31.5 (9.5)
Gait speed (m/s)	1.46 (0.21)	1.38 (0.21)

Note. All variables are presented as mean (SD) unless indicated otherwise. IQR = interquartile range;

BMI = body mass index; SM = skeletal muscle mass; SMI = skeletal muscle mass index.

^aHistory of falls defined as the presence of at least one fall in the previous 12 months.

^bMultimorbidity defined as ≥ 2 of the following diseases: hypertension, myocardial infarction, stroke, chronic obstructive pulmonary disease, cancer, diabetes mellitus, osteoarthritis, and Parkinson's disease.

^cData available in a subgroup of *n* = 153 young-to-middle-aged adults and *n* = 76 older adults.

per day was positively associated with SM% (association was lost after additional adjustment for body mass) and handgrip strength (in both models), but not with the other muscle-related parameters. Mean duration of inactive periods was positively associated with SM in kilograms (association was lost after additional adjustment for fat mass), but not with the other muscle-related

parameters. Comparing the effect sizes, I-PA was most strongly associated with handgrip strength in young-to-middle-aged adults (Table 2).

In older adults, active duration, number of active periods, and number of steps were inversely associated with SMI (association was lost after additional adjustment for fat mass) and positively associated with gait speed (in both models), but not with the other muscle-related parameters. Mean duration of active periods was not associated with muscle-related parameters. Inactive duration was positively associated with SMI (association was lost after additional adjustment for fat mass) and inversely associated with gait speed (in both models), but not with the other muscle-related parameters. Number of inactive periods was positively associated with gait speed (in both models), but not with the other muscle-related parameters. Mean duration of inactive periods was inversely associated with gait speed (in both models), but not with the other muscle-related parameters. Comparing the effect sizes, I-PA was most strongly associated with gait speed in older adults (Table 3).

Figure 1 visualizes the associations between I-PA, expressed as number of steps and inactive duration, and the standardized muscle-related parameters in young-to-middle-aged and older adults.

Results of the association between I-PA and muscle-related parameters in the total population did not change the conclusions of the results in the age-stratified groups (Supplementary Table 1).

Discussion

In this study, the associations between I-PA and muscle-related parameters were found to be variable and highly dependent on chronological age. I-PA was most strongly associated with handgrip strength in young-to-middle-aged adults and with gait speed in older adults. I-PA was not associated with muscle mass.

The results indicate an age-related transition point at which associations between physical activity and muscle-related parameters change. Muscle-related parameters may have different age-related transition points; muscle mass was found to decline after the age of 50 years with 1% to 2% per year (Buford et al., 2010; Mitchell et al., 2012); handgrip strength was estimated to decline gradually with 0.06 kg per year between the ages of 20 and 50 years and to decline steeper after the age of 50 years with 0.37 kg per year (Beenakker et al., 2010), whereas gait speed was found to decline after the age of 70 years with 1% per year and declines steeper after the age of 80 years with 4% per year (Forrest, Zmuda, & Cauley, 2006; Hall et al., 2016; Himann, Cunningham, Rechnitzer, & Paterson, 1988). Transition points for physical activity are less clear; however, it is suggested that physical activity declines steeper around the age of 60 years (Hall et al., 2016; Schrack et al., 2014).

Table 2. Associations Between l-PA and Standardized Muscle-Related Parameters in Multivariate Linear Regression Models in Young-to-Middle-Aged Adults.

	SM (kg)			SM (%)			SMI (kg/m ²)			Handgrip strength (kg)			Gait speed (m/s)		
	n = 153			n = 153			n = 153			n = 156			n = 156		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
Active duration (minutes/day)															
Model 1: age + sex	-.002	.001	.091	.000	.001	.709	-.001	.001	.674	.001	.001	.334	.001	.001	.537
Model 2: as 1 + outcome specific ^a	-.002	.001	.203	-.001	.001	.431	.000	.001	.792	.002	.001	.043	.001	.001	.264
Number of active periods (per day)															
Model 1: age + sex	-.015	.018	.395	.003	.017	.843	.004	.018	.803	.022	.017	.195	.019	.019	.305
Model 2: as 1 + outcome specific ^a	-.009	.017	.591	-.007	.014	.619	.013	.016	.432	.032	.016	.043	.025	.018	.169
Mean duration of active periods ^b (seconds/period)															
Model 1: age + sex	-.006	.039	.887	-.014	.036	.701	-.013	.038	.739	-.038	.035	.276	-.026	.039	.509
Model 2: as 1 + outcome specific ^a	-.017	.038	.658	-.004	.031	.886	-.028	.035	.429	-.041	.033	.212	-.025	.038	.520
Number of steps ^c (per day)															
Model 1: age + sex	-.007	.026	.781	.050	.024	.036	.002	.026	.929	.051	.024	.037	.026	.027	.332
Model 2: as 1 + outcome specific ^a	.013	.026	.613	.027	.021	.195	.030	.024	.209	.064	.023	.006	.029	.026	.280
Inactive duration (hours/day)															
Model 1: age + sex	.061	.069	.379	-.012	.064	.855	-.013	.068	.846	-.061	.064	.347	-.081	.071	.254
Model 2: as 1 + outcome specific ^a	.039	.067	.558	.028	.055	.613	-.044	.062	.484	-.101	.061	.099	-.107	.070	.129

(continued)

Table 2. (continued)

	SM (kg)			SM (%)			SMI (kg/m ²)			Handgrip strength (kg)			Gait speed (m/s)		
	n = 153			n = 153			n = 153			n = 156			n = 156		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
Number of inactive periods (per day)															
Model 1: age + sex	-.176	.096	.070	.088	.089	.325	-.155	.095	.104	-.160	.089	.075	.101	.099	.311
Model 2: as 1 + outcome specific ^a	-.124	.094	.186	-.017	.078	.825	-.084	.088	.343	-.102	.086	.240	.125	.098	.201
Mean duration of inactive periods ^b (minutes/period)															
Model 1: age + sex	.066	.032	.042	-.045	.029	.131	.056	.032	.078	.028	.030	.352	-.050	.033	.129
Model 2: as 1 + outcome specific ^c	.044	.031	.163	-.002	.026	.927	.025	.030	.391	.004	.029	.891	-.060	.032	.068

Note. Muscle-related parameters were standardized into gender-specific z scores. Interpretation: One SD increase of I-PA is associated with an effect size times standard deviation ($\beta \times SD$) higher/lower of the muscle-related parameters. The p values in bold are statistically significant.

I-PA = instrumented assessment of physical activity; SM = skeletal muscle mass; SMI = skeletal muscle mass index (kg/m²).

^aOutcome-specific adjustments: SM (kg) for fat mass (kg), SM (%) for body mass (kg), SMI for fat mass (kg), handgrip strength for height + body mass (kg), and gait speed for height.

^bMean duration of active and inactive periods / 100.

^cNumber of steps per day / 1,000.

Table 3. Associations Between I-PA and Standardized Muscle-Related Parameters in Multivariate Linear Regression Models in Older Adults.

	SM (kg)			SM (%)			SMI (kg/m ²)			Handgrip strength (kg)			Gait speed (m/s)		
	n = 76			n = 76			n = 76			n = 80			n = 80		
	β	SE	p	β	SE	p	β	SE	p	β	SE	p	β	SE	p
Active duration (minutes/day)															
Model 1: age + sex	-.003	.002	.072	.001	.002	.455	-.004	.002	.023	.002	.001	.279	.005	.002	.004
Model 2: as 1 + outcome specific ^a	-.002	.002	.169	-.001	.001	.660	-.003	.002	.096	.002	.001	.108	.005	.002	.004
Number of active periods (per day)															
Model 1: age + sex	-.044	.026	.093	.012	.025	.645	-.060	.029	.045	.027	.022	.231	.072	.025	.006
Model 2: as 1 + outcome specific ^a	-.034	.026	.182	-.013	.023	.555	-.041	.027	.128	.036	.021	.089	.073	.025	.005
Mean duration of active periods ^b (seconds/period)															
Model 1: age + sex	.017	.052	.746	.017	.050	.738	.027	.059	.647	-.023	.043	.594	-.038	.052	.466
Model 2: as 1 + outcome specific ^a	.016	.051	.752	.018	.044	.678	.026	.053	.632	-.021	.040	.605	-.037	.051	.474
Number of steps ^c (per day)															
Model 1: age + sex	-.068	.044	.124	.044	.042	.303	-.100	.049	.045	.052	.038	.173	.182	.041	<.001
Model 2: as 1 + outcome specific ^a	-.052	.043	.237	-.001	.039	.987	-.069	.45	.133	.066	.036	.070	.182	.041	<.001
Inactive duration (hours/day)															
Model 1: age + sex	.166	.095	.084	-.051	.092	.581	.234	.107	.031	-.091	.081	.267	-.250	.093	.009
Model 2: as 1 + outcome specific ^a	.127	.094	.182	.047	.084	.576	.159	.099	.112	-.126	.077	.105	-.252	.093	.008

(continued)

Table 3. (continued)

	SM (kg)			SM (%)			SMI (kg/m ²)			Handgrip strength (kg)			Gait speed (m/s)		
	<i>n</i> = 76			<i>n</i> = 76			<i>n</i> = 76			<i>n</i> = 80			<i>n</i> = 80		
	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>	β	SE	<i>p</i>
Number of inactive periods (per day)															
Model 1: age + sex	.153	.285	.593	.389	.268	.150	.000	.325	.999	.219	.243	.370	.622	.282	.031
Model 2: as 1 + outcome specific ^a	.283	.278	.312	.289	.238	.229	.230	.294	.436	.170	.227	.455	.589	.283	.041
Mean duration of inactive periods ^b (minutes/period)															
Model 1: age + sex	.019	.042	.654	-.059	.040	.142	.061	.047	.200	-.041	.035	.254	-.116	.041	.005
Model 2: as 1 + outcome specific ^a	-.007	.042	.876	-.027	.036	.458	.016	.044	.718	-.041	.034	.234	-.112	.041	.007

Note. Muscle-related parameters were standardized into gender-specific z scores. Interpretation: One SD increase of I-PA is associated with an effect size times standard deviation ($\beta \times$ SD) higher/lower of the muscle-related parameters. The *p* values in bold are statistically significant.

I-PA = instrumented assessment of physical activity; SM = skeletal muscle mass; SMI = skeletal muscle mass index (kg/m²).

^aOutcome-specific adjustments: SM (kg) for fat mass (kg), SM (%) for body mass (kg), SMI for fat mass (kg), SMI for fat mass (kg), handgrip strength for height + body mass (kg), and gait speed for height.

^bMean duration of active and inactive periods / 100.

^cNumber of steps per day / 1 000.

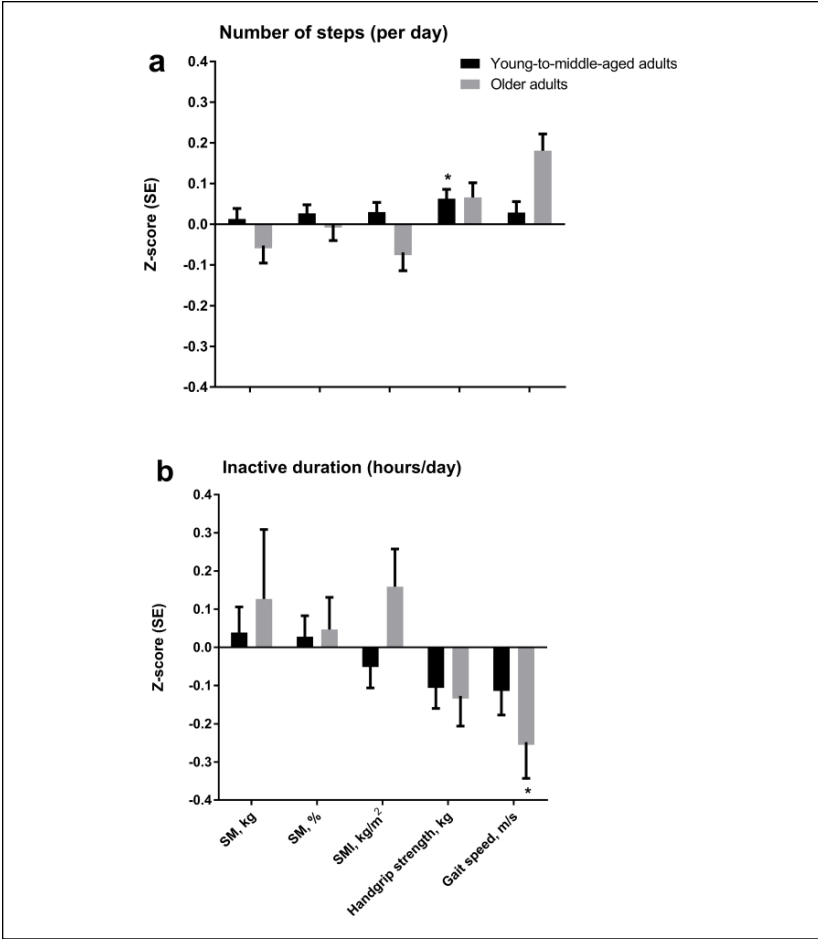


Figure 1. Associations between instrumented assessment of physical activity and standardized muscle-related parameters in young-to-middle-aged and older adults for (a) number of steps (per day) and (b) inactive duration (hours/day). *Note.* Muscle-related parameters are presented as gender-specific z scores (SE). SM = skeletal muscle mass; SMI = skeletal muscle mass index. The *p* values were calculated with multivariate linear regression models including adjustments for age, sex, and outcome-specific adjustments. **p* < .05. ***p* < .001.

Age-related changes in handgrip strength as suggested by Beenakker et al. (2010) may explain differences in association between I-PA and handgrip strength between the young-to-middle-aged and older adults. A previous

study showed that questionnaire-based higher daily physical activity was associated with higher handgrip strength in community-dwelling adults aged 65 years and older (Hwang et al., 2016). The present study was not able to show this association, and this may be explained by the use of I-PA instead of a questionnaire when compared with the study by Hwang et al. (2016). Differences in association between the young-to-middle-aged adults and older adults may be driven by aforementioned age-related declines or may be attributable to handgrip strength because of the dissociation between handgrip strength and quadriceps strength in older adults (Chan, van Houwelingen, Gussekloo, Blom, & den Elzen, 2014).

I-PA was found to be associated with gait speed in older adults but not in young-to-middle-aged adults. A possible explanation is that gait speed remains relatively preserved until the age of 70 years (Forrest et al., 2006; Hall et al., 2016; Himann et al., 1988). Therefore, it is expected to find an association between I-PA and gait speed in older adults and not in young-to-middle-aged adults.

The muscle-related parameters in this study comprise both measures of muscle function (i.e., handgrip strength and gait speed), and muscle mass (i.e., absolute and relative muscle mass). No associations were found between I-PA and muscle mass. This is in contrast with other studies that showed that questionnaire-based daily physical activity and moderate-to-intense physical activity were positively associated with absolute muscle mass in older adults (Baumgartner et al., 1999; Mijnders et al., 2016; Raguso et al., 2006). A potential explanation could be that not only being active but also the intensity of this activity (as more intense activities might be easier to recall) may play a role in retaining muscle mass. However, the lack of associations of I-PA with muscle mass and strong associations of I-PA with muscle function suggest that muscle function and not muscle mass might be more relevant for daily physical activities. This is in line with the finding that maintaining or gaining muscle mass did not prevent the loss of muscle strength in healthy older adults (Goodpaster et al., 2006). These findings suggest a role for other age-related factors affecting muscle function like increased levels of proinflammatory cytokines (Roubenoff, 2003), selective loss of type 2 muscle fibers (Lexell, Downham, & Sjostrom, 1986), myosteatosis (Goodpaster et al., 2001), and loss of motor units (Drey et al., 2016). Alternatively, the lack of associations between I-PA and muscle mass could be the selection of the predominantly vital and motivated group of socially active participants resulting in a ceiling effect. A previous study in community-dwelling older males has found an association between objectively measured moderate-to-vigorous physical activity and a reduced risk of sarcopenia defined by the European Working Group on Sarcopenia in Older People (EWGSOP) definition (Aggio et al., 2016).

Previous studies showed that self-reported physical activity both overestimates and underestimates actual physical activity (Prince et al., 2008). Recalling physical activity could be seen as a complex cognitive task, and many questionnaires are not validated for the full range of physical activity characteristics (Sallis & Saelens, 2000). The present study confirmed this by revealing a large discrepancy between self-reported and instrumentally assessed fulfillment of the Dutch physical activity guideline. Therefore, a valid estimation of daily physical activity requires the use of instruments as pedometers or accelerometers. Accelerometers provide more detailed information concerning the amount, types (i.e., walking, standing, sitting, and lying), and patterns of daily physical activity.

To the best of our knowledge, this study is the first to describe the association between I-PA and muscle mass, handgrip strength, and gait speed in young-to-middle-aged and older adults. A strength of this study is the use of accelerometry to objectively quantify actual amount and type of physical activity. As a consequence of recruiting participants from a lecture evening, a relative vital and motivated group of socially active young-to-middle-aged and older adults was included, which is also indicated by the high wearing time of the accelerometers. This resulted in a fairly homogeneous study population that could be seen as a limitation. Longitudinal studies are needed for better determination of transition points with age as the cross-sectional design of the present study does not allow to determine the associations between I-PA and muscle-related parameters change over time.

Conclusion

I-PA was most strongly associated with handgrip strength in young-to-middle-aged adults and with gait speed in older adults, but not with muscle mass in either age group. These results indicate the importance of muscle function and its dependency on chronological age. The lack of an association between I-PA and muscle mass might indicate the relevance of muscle function rather than muscle mass. The use of objectively measured physical activity is recommended as it provides objective and detailed information concerning daily physical activity. Future research should focus on unraveling the association between I-PA and the change of muscle mass, muscle strength, and gait speed in a longitudinal study design performed in heterogeneous study populations.

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Declaration of Conflicting Interests

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Supplemental Material

Supplemental material is available for this article online.

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